

# Breakfast of Champions: The Importance of Fruit in the Cognitive Evolution of Great Apes

by

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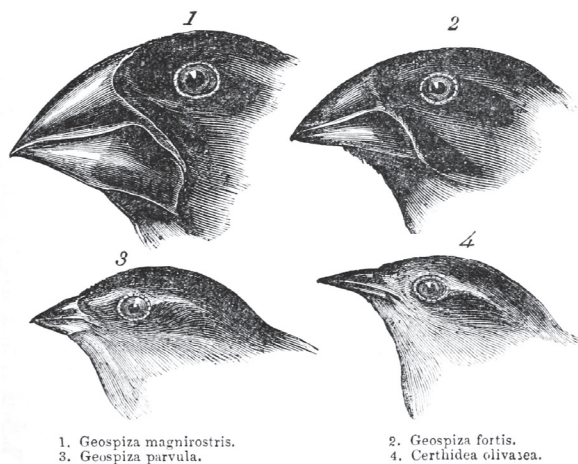
## Introductory Review

Prior to class, please read the following article:

Potts, R. 2004. Paleoenvironmental basis of cognitive evolution in great apes. *American Journal of Primatology* 62: 209–28.

## Questions

1. What are the four conditions that must be met for natural selection to produce change in a population?
2. Galapagos finches are a group of species with many different beak shapes. Many of these shapes are adaptations more suited to feed from a certain food source. Match the beak shape of the finches in Figure 1 below to the food they eat (check or fill the matching food box for each species in the table).



	Leaves, Fruit	Seeds	Insects, Nectar	Termites with Tools
1 Ground finch				
2 Vegetarian finch				
3 Woodpecker finch				
4 Warbler finch				

Figure 1. Galapagos finches by J. Gould, PD, [https://commons.wikimedia.org/wiki/File:Darwin%27s\\_finches\\_by\\_Gould.jpg](https://commons.wikimedia.org/wiki/File:Darwin%27s_finches_by_Gould.jpg).



## Part I – Meet Mukah

Mukah was raised by a sweet elderly couple who loved to pamper him. They also taught him to do things like brush his teeth and comb his own hair. However, Mukah quickly grew from an infant to a full-sized male weighing over 70 kg. While these things may seem perfectly normal, his family soon had to give him up and sent him to live somewhere else. Why? Mukah is a full grown male orangutan!

Orangutans are one of five great ape species: orangutans, chimpanzees, bonobos, gorillas, and humans. Gibbons (lesser apes) and the five great apes branched from old world monkeys about 30 million years ago (Figure 2). Of the true great apes, orangutans are the most distant and branched off from the evolutionary trajectory of great apes about nine million years ago, which was nearly four million year earlier than any others.

Orangutans share a lot in common with humans, but there are also many differences between the two. For one, humans expanded across the globe while orangutans and other great apes inhabited only a few places, all of which are shrinking rapidly. Humans also eat a more varied diet, while orangutans rely mainly on fruit.

To understand why humans now face such a different fate from their close relative, the orangutan, we

must look back through geologic history to the end of the Miocene epoch, a time approximately 23 million years ago when climates were changing and the availability of fruit was no longer something to be taken for granted.

During the late Miocene epoch, dramatic climate and geographic changes reshaped the old world continents (Potts, 2004). There are two primary geological records of this shift. The first was an accumulation of Aeolian dust on the sea floor, which indicates a change in wind strength, seasonality, and the amount of vegetation cover in Africa where the dust originated (deMenocal, 1995). The second indicator is several layers of dark and organically rich soil, referred to as sapropels, in marine areas of the Mediterranean. These layers imply flooding of the Nile River, heavy rainfall, and an increase in lakes, wetlands, and other bodies of water (Rossignol-Strick, 1985). These changes in the landscape and climate ultimately influenced plant life, more specifically, the ability of large fruits (such as durians and figs) to grow and in which seasons. Changing resources quickly began to put pressure on species that relied on a frugivorous diet. This pressure, referred to as natural selection, was strong enough to shape the evolutionary trajectory of the great apes we see today. While we may not initially think of fruit as a key selective pressure, it was a surprisingly important resource that ultimately propelled this family to become what they are today—intelligent, social creatures that are remarkably like ourselves.

### Questions

1. How might Aeolian dust and sapropel layers indicate changes in the environment?
2. How might changes in climate and flooding affect resource availability for great apes?

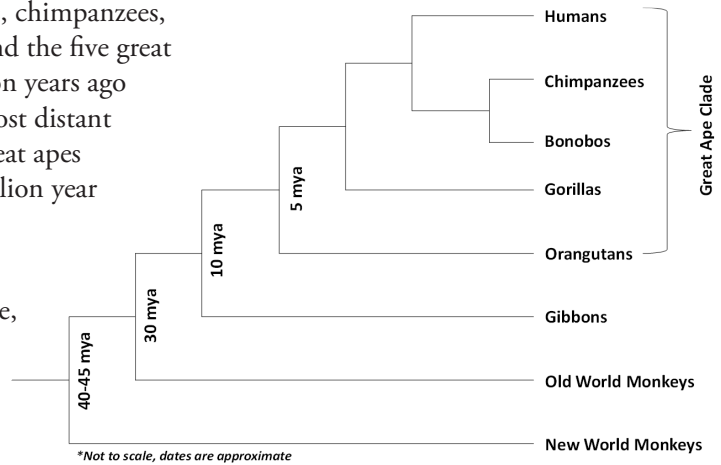


Figure 2. Primate phylogeny.

## Part II – Mukah's Ancestors

Because of his past relationship with humans, Mukah is very social and, for an orangutan, fairly laid back. Of course this is not a trait he shares with all great apes, and despite his demeanor he could be incredibly dangerous. A full-grown male orangutan has the strength of seven NFL football players, even if he's just playing (Favreau, 2016). Seeing his large stature up close and watching his enormous teeth when he munches on large chunks of mango and pineapple, one can neither doubt his strength nor deny his intimidating stature—just look at King Louie from the movie *The Jungle Book*!

How much fruit does it take to feed such a large and energetic individual? A fully grown male orangutan like Mukah may eat between 3800 and 8400 Kcal a day (Knott, 1998). Mukah is fed a mix of fruit and grains several times a day to make sure he stays healthy. Of course our own human diets are very different from these fruit-centered meals. For example, species in the genus *Homo* such as ourselves often cook food. Such differences in diet may be one of the reasons for the cognitive and morphological differences between humans and apes. Early apes were very diverse and existed across the old European continent. However, during the later portion of the Miocene shift, many of the varied traits that differed between the great apes, including diet and morphology, began to decline in diversity.

At first, the ape species that had once inhabited much of the European continent simply migrated to reside in low latitude areas of Asia and Africa (Jablonski, 1998). However, many species ultimately died off because they were unable to survive new conditions. These early apes had teeth well-adapted to the fruit rich environment they had previously inhabited. But with a changing climate and a migration south, their existing traits were not initially suited to handle a tougher environment with less readily-available fruit. Changes in seasonal patterns made fruit supply less predictable and less consistently available. However, the apes were highly specialized, with dental morphology that was suited to the types of food they ate. For example, flat molars are suited for crushing and grinding fibrous foods such as leaves and seeds. In contrast, teeth with crests are more suited for gripping and slicing fleshier fruits.

One might expect that possessing this specialized dental morphology in an environment with less available fruit would be a problem for the apes. However, the great apes of the Miocene seem to have adaptations that allow them to better survive in this new environment and in a way very different than one might expect. Instead of finding other food sources, apes today are still heavily reliant on fruit for dietary needs. The structure of early ape molars had low crests along the edges, a form that indicates a continued reliance on fruit, suggesting dependence on an arboreal, fruit-producing environment. Analysis of the wearing patterns on the teeth of early Miocene apes is an additional indicator that a great ape species still consumed soft-fruit foods (Potts, 2004). However, some diversification and development of the ability to eat harder foliage was certainly occurring among great apes as the Miocene progressed (Potts, 2004). Most of today's great apes follow this pattern. For example, bonobos and orangutans both rely primarily on fruit as their food source, though a few other species, like gorillas, have added some foliage (i.e., leaves) into their diet. Even with the addition of leaves, fruit remains a majority of the food eaten and is an important dietary staple of these apes. But how did the apes manage to hold on to their frugivorous diet despite the growing difficulty of actually finding enough fruit to eat?

Current research suggests that many traits we now recognize in the great apes were key in sustaining their ancestral or original diet and habitat biases (Potts, 2004). Instead of developing adaptations that allowed them to make use of other more available options, the apes developed other traits to become more effective at using the limited resources they had. Among these traits are the remarkable intelligence and complex social structure that so closely mirror that of our own species.

Despite these traits, the great apes in the Miocene still faced adaptive issues. Competition for food led to direct interaction with other individuals, necessitating either competition or collaboration. The difficulty of finding ripe fruit in a large forest demanded advanced spatial cognition. Lacking these social or cognitive skills would likely have led to starvation, with only the skilled individuals surviving to reproduce. These skills, originating as variation in a population, seem to have been selected for by an unpredictable environment that demanded such flexibility in exchange for survival. Today, the great apes display complex interactions with their environment. This includes considerable social skill, an ability to manipulate their surroundings, and impressive locomotor function.



## Part III – Mukah’s Future

Today, Mukah lives happily in a zoo; however, both the Sumatran and Bornean orangutan species are endangered and at high risk of extinction in the wild (Nater *et al.*, 2013; Spehar *et al.*, 2015). Unfortunately, Mukah will probably never reproduce because his isolation from other orangutans during his formative years means he never learned proper mating behaviors and is unlikely to successfully mate with a female. Sadly, his genes will not persist in the shrinking orangutan gene pool. This is particularly unfortunate because most populations of great apes suffer from significant inbreeding (Prado-Martinez *et al.*, 2013). However, he is safe from poaching and not at risk of starvation because he lives in a zoo and does not face threats he might if he lived in his natural habitat.

Even if an intelligent and social ape like Mukah were to rejoin the natural population and reproduce, he and his fellow orangutans might still find themselves nearing extinction. A great many factors guided the evolutionary trajectory of the great apes and selected for the qualities we see in them today, but their stubborn commitment to a highly specialized fruit diet provided a base for their evolutionary history. With changes in climate and seasons limiting fruit resources, versatility became a beneficial adaptation. This versatility came in many forms, one being an emphasis on social groupings. Sociality allowed for sharing of fruit patches, feeding opportunities, and habitat among other things. Intelligence also became adaptive, with cognitive skills allowing apes to better solve problems caused by a constantly changing habitat. However, while these traits may once have been a better alternative to simple finding a new food source, they may now be more detrimental than beneficial.

Persistence of the frugivorous diet may have ultimately placed great apes in a “cognitive trap.” While they have exceptional intelligence that allows them to maintain their needs even with environmental variation, this reliance on a single resource (fruit) is a weakness for survival in disappearing forests. With habitat loss, these apes move closer to the extinction that they have already escaped so many times along a complex evolutionary trajectory. While natural selection has fostered the frugivorous diet, this trait is no longer adaptive and may even become something that is harmful to the species.

### Questions

1. Remembering the conditions required for natural selection, how are each met in the context of the evolution of primate diet and reliance on fruit?
2. How, without access to living individuals of the Miocene great apes, can researchers conclude that natural selection has occurred for a species?
3. What is a trade-off? Give one example of a trade-off in great apes. Is the “cognitive trap” in orangutans an example of a trade-off? Explain if so.





## Glossary

*Great ape*—An ape that belongs to the family Hominidae, including humans, gorillas, orangutans, chimpanzees, and bonobos.

*Miocene Epoch*—A geological time period from 20–5 mya occurring between the Oligocene and Pliocene epochs during which the climate began to change dramatically.

*Life history trait*—Characteristics of a species, such as anatomy, behavior, reproductive development, or life span that have been shaped by natural selection and affect an organism's ability to survive.

*Trade off*—A situation in which one quality or trait is lost or limited due to another quality (e.g. clutch size and offspring size).

*Natural selection*—A process causing differential survival of individuals based on their expressed phenotype. Individuals with phenotypes more suited to their survival in the environment are more likely to live long enough to reproduce and pass on their genes. This differential persistence of certain phenotypes can influence the composition of a population.

*Adaptation*—A behavioral or physiological change that allows an organism to be better suited to and more successful in their environment.

*Frugivore*—An organism that relies on fruit as its main source of food.

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